OPTICAL METHODS FOR PLANETARY LANDING SITE CERTIFICATION. M. K. Shepard, Department of Geography and Earth Science, Bloomsburg University, 400 E. 2nd St., Bloomsburg, PA 17815, mshepard@planetx.bloomu.edu.

The process of choosing sites for planetary soft landers and rovers is one of compromise between interesting and important science, and mission safety. Among the engineering constraints considered in site selection is surface roughness - what is the probability of a catastrophic failure caused by landing on a boulder, steep slope, or precipice? Even structural features as small as a meter in size could cause such a catastrophe, yet features of this size are not resolvable by any orbiter imagery. The high resolution Mars Observer Camera (MOC) carried on Mars Global Surveyor will have a resolution limit of 1.4 m/pixel [1]. Even at this fantastic scale, many landing obstacles will not be resolved. The purpose of this work is to outline a few techniques that will allow landing obstacles as small as ½ meter in size to be inferred from high resolution MOC or other imagery.

Background: The methods of spatial statistics, i.e., the statistics of image "texture", have been developed by a number of workers [2–4], although the application of these methods to real images is still rather rare. In the terminology of this field, a "scene" is the intrinsic nature of an area being examined, while an "image" is an imperfect rendition of the scene as measured by an intermediate optical system. In essence, an image is formed by the convolution of the sensor point-spread function, and is further modified by instrument or other noise. Throughout this work, the term "structure" will be used to refer to any inhomogeneity in a scene - whether due to variations in composition, scattering properties, or shadowing. It is assumed that the methods outlined are being applied to a portion of an image with a single geologic provenance. The existence of disparate genetic or modification processes within an analytical region may invalidate the analysis.

The statistical tools utilized in this work include the mean radiance (actually the mean raw DN value which is a linear function of radiance), the standard deviation of radiance about the mean as a function of pixel size, the histogram of pixel DN's for a given area, and the semivariogram of the image. The semivariogram is defined as

$$\nu^2 = E\{[r(x,y) - r(x+\Delta x,y+\Delta y)]^2\}$$

where E is the expectation value (average), r is the radiance of a pixel at coordinates (x,y), and $r(x+\Delta x,y+\Delta y)$ is the radiance of a pixel displaced from the first by an incremental amount in the x and y directions. Typically, it is assumed that the image is isotropic and the variogram becomes a function only of the distance separating pixels, h. Jupp and others [2,3] have shown that, under conditions of stationarity, the variogram can also be found from

$$\nu^2 = \sigma^2 - \mathrm{Cov}(h)$$

where σ^2 is the variance of the entire image, and Cov(h) is the covariance of the image with itself shifted an incremental distance, or lag, of h.

Application: Several images, most with known ground truth, were examined to determine their sensitivity to subpixel scale structure. Among the images examined were digitized airphotos of Mars Hill, Death Valley; SPOT 10 m digital data over the Hickory Run State Park Boulder Field, Pennsylvania; high resolution Viking Orbiter images of the Viking Lander 1 site in Chryse Planitia; and high resolution images of a portion of the Mars Pathfinder landing ellipse. This analysis provides the following results, many of which can be understood in light of previous theoretical and empirical work.

Results: (1) The mean radiance or reflectance of an imaged scene is a constant, independent of the pixel dimensions that make up the image [2].

(2) The variance (and standard deviation) of radiance in an image decreases as pixel size increases. This property is well-known from statistics. For any random variable distribution, the standard deviation about the mean decreases as the square-root of sample size [5]. Therefore, for any given scene, one would expect the standard deviation of radiance about the mean to increase as the pixel size approaches (from above) the dominant scale of surface structure [2–4].

(3) The semivariogram of an image at a lag of 1 pixel is sensitive to the scale of structure just below the scale of the pixel [2–4]. If the dominant scale of structure is much smaller than the pixel size, the semivariogram at a lag of one pixel will equal the standard deviation of the entire image. If the dominant scale is on the order of 25–100% of the pixel size, the semi-variogram at a lag of one pixel will be significantly lower than the standard deviation of the image [2–4].

(4) Because of the presence of non-random structures, the histogram of radiance from a scene will rarely obey Gaussian statistics. However, as the pixel size of the associated image is increased beyond the scale of the dominate surface structure, the histogram of radiance will approach a Gaussian form. This is simply an application of the Central Limit Theorem of statistics [5]. Therefore, a measurement of the asymmetry of the histogram, such as the skew (third moment), can be used to infer the presence of significant structure below the scale of the pixel.

Conclusions: By a careful analysis of the above four properties of an imaged area, it is possible to infer the existence of subpixel scale structure. These results should be of immediate applicability to those examining potential soft-landing sites. Additionally, further refinement of these methods may lead to new methods of classifying geologic terrains and potentially the inferrence of terrain genesis and/or surficial processes acting on those terrains.

References: [1] Malin et al., 1992, JGR **97**, 7699. [2] Jupp et al., 1988, Trans. IEEE **26**, 463. [3] Jupp et al., 1989, Trans. IEEE **27**, 247. [4] Woodcock et al.,1988, Rem. Sens. Env. **25**, 323. [5] Hoel, 1984, Introduction to Mathematical Statistics, Wiley, NY, NY.